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Tanimura

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(54) **METHOD OF ASSEMBLING AND ADJUSTING A MULTI-BEAM SCANNING OPTICAL APPARATUS AND METHOD OF MANUFACTURING A MULTI-BEAM SCANNING OPTICAL APPARATUS**

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(22) Filed: **Jul. 2, 2012**

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Jun. 14, 2012 (JP) 2012-134981

(51) **Int. Cl.**

H01S 4/00	(2006.01)
G02B 26/12	(2006.01)
B41J 2/47	(2006.01)
G06K 15/12	(2006.01)
G02B 26/08	(2006.01)

(52) **U.S. Cl.**

CPC ***G02B 26/126*** (2013.01); ***B41J 2/473*** (2013.01); ***G02B 26/0825*** (2013.01); ***G02B 26/127*** (2013.01); ***G06K 15/1219*** (2013.01); ***G06K 15/1257*** (2013.01); *G02B 26/123* (2013.01); *Y10T 29/49002* (2015.01)

(58) **Field of Classification Search**

CPC B41J 2/473; G06K 15/1219; G06K 15/1257; Y10T 29/49002; Y10T 29/49; G02B 26/0825; G02B 26/126; G02B 26/127; G02B 26/123

USPC 29/592.1; 358/1.4, 1.5, 1.9, 526; 359/202.1, 204.1, 204.4, 210.2, 206, 359/205.1; 347/225, 244, 258, 241, 129, 347/231, 237, 256, 261, 259

See application file for complete search history.

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(57) **ABSTRACT**

Provided is a method of assembling and adjusting multi-beam scanning optical apparatus including a light source unit having multiple light emitting points, a deflecting unit configured to deflect multiple light beams emitted from the light source unit, and an imaging optical system configured to image the multiple light beams deflected by the deflecting unit on a surface to be scanned, the method including: adjusting incident positions of the multiple light beams in a sub-scanning direction, which are entered into an imaging optical element constituting the imaging optical system to adjust irradiated positions of the multiple light beams on the surface to be scanned; and adjusting the irradiated positions of the multiple light beams on the surface to be scanned in the sub-scanning direction without changing the incident positions.

10 Claims, 13 Drawing Sheets

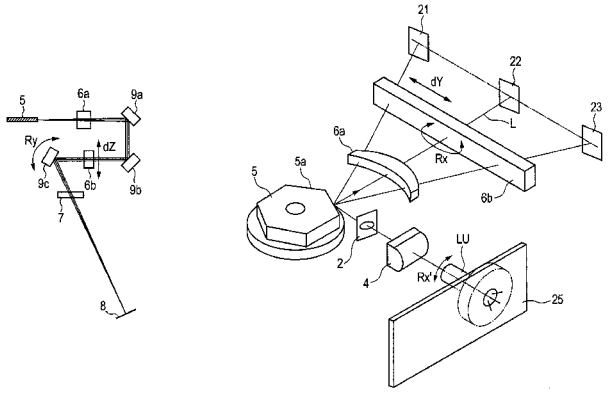


FIG. 1A

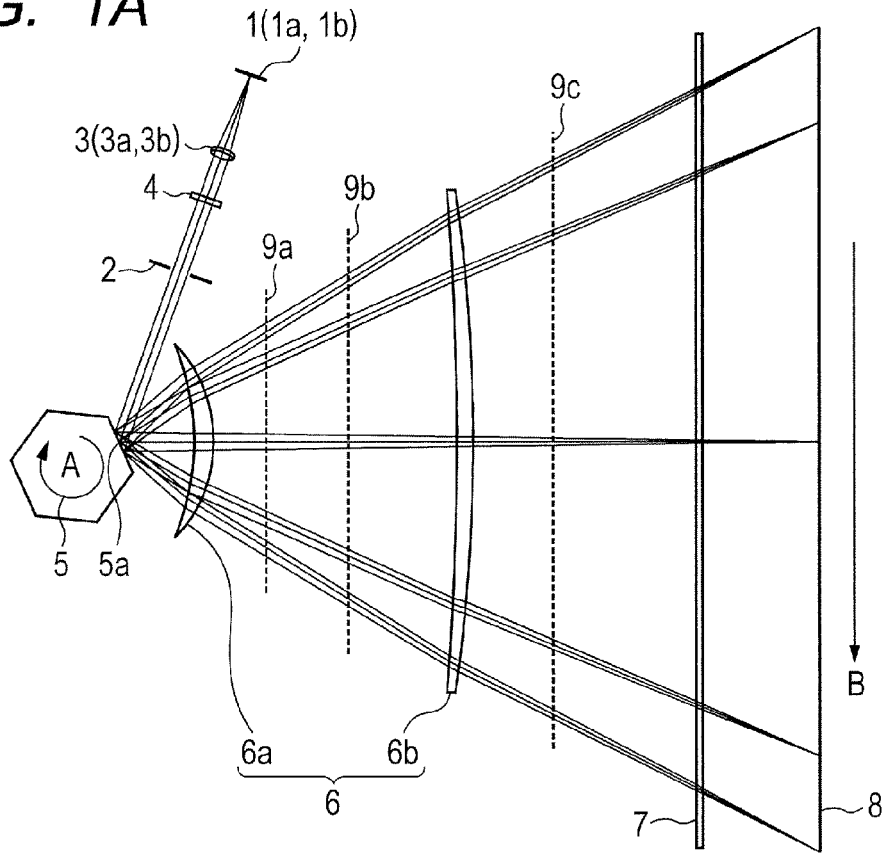


FIG. 1B

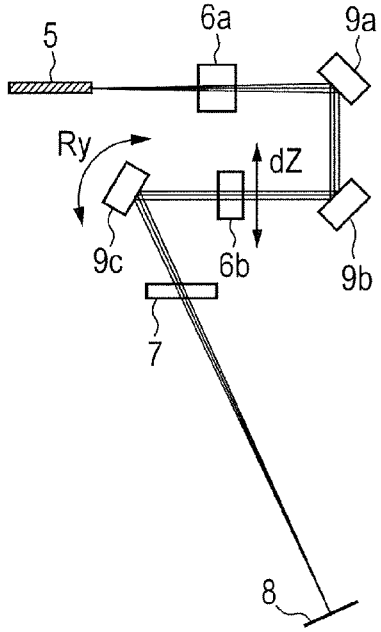


FIG. 2A

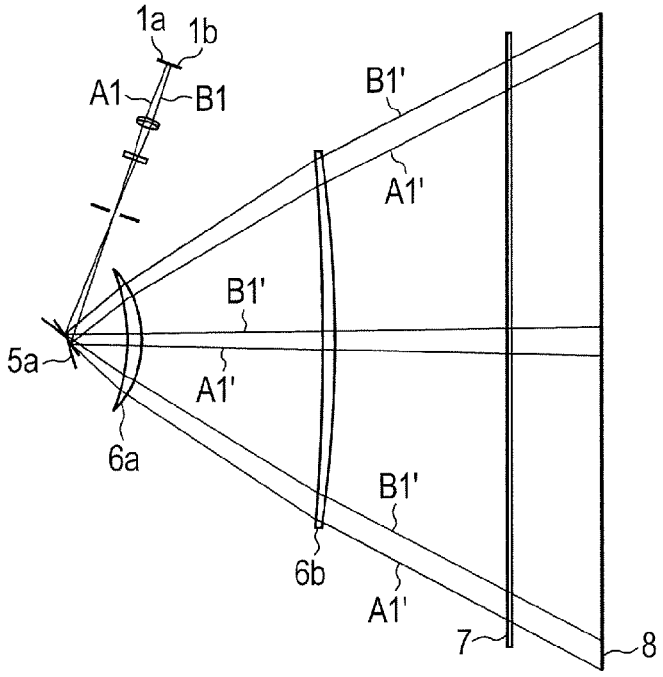

1a
1b
A1
B1
B1'
A1'
B1'
5a
A1'
6a
B1'
6b
A1'
7
8

FIG. 2B

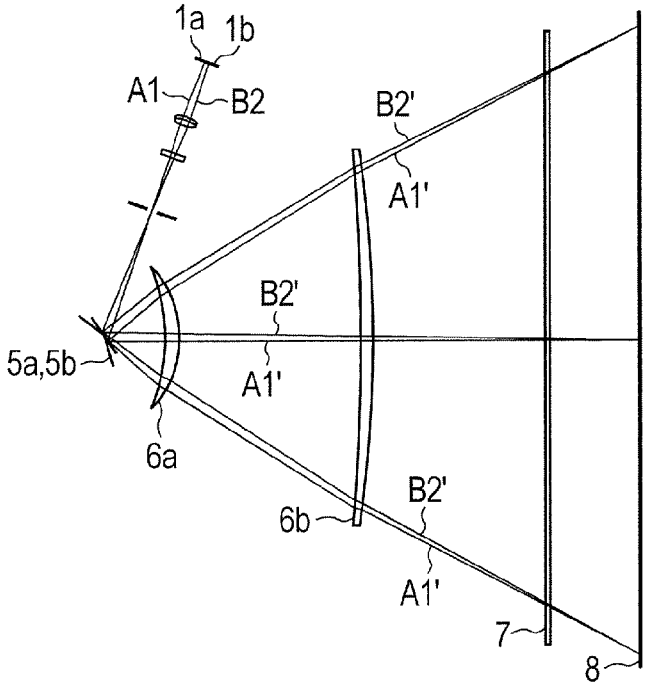

1a
1b
A1
B2
B2'
A1'
B2'
5a,5b
A1'
6a
B2'
6b
A1'
7
8

FIG. 3A

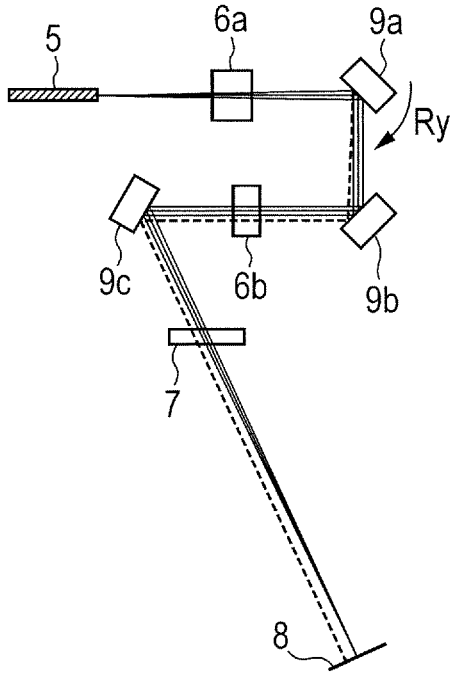


FIG. 3B

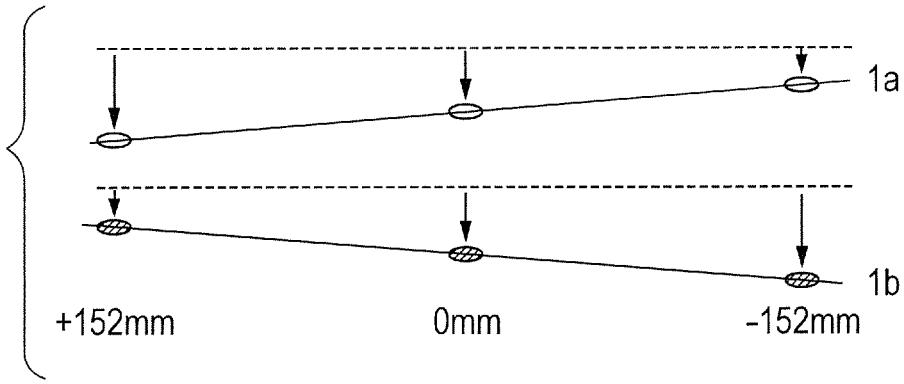


FIG. 4

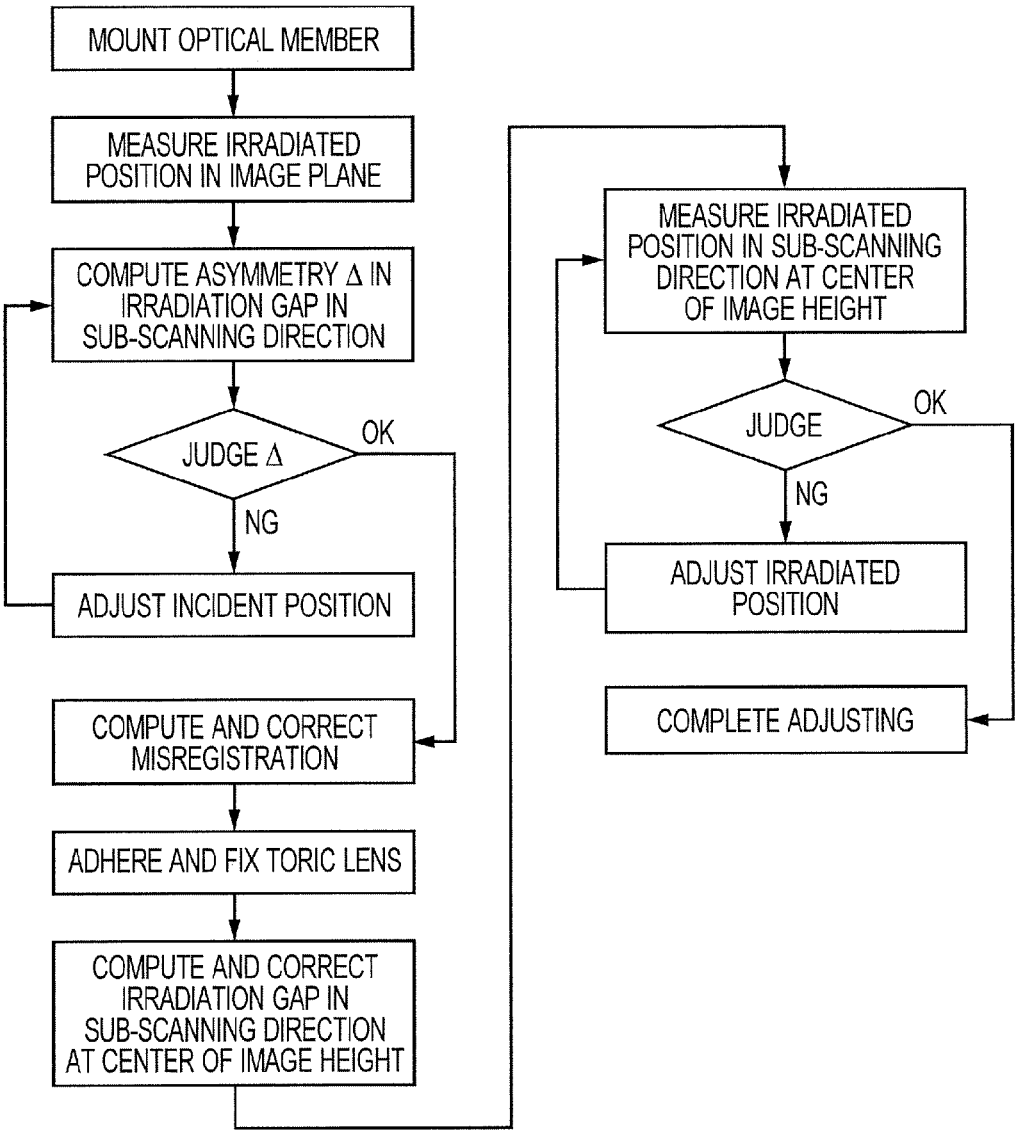

MOUNT OPTICAL MEMBER
MEASURE IRRADIATED POSITION IN IMAGE PLANE
COMPUTE ASYMMETRY Δ IN IRRADIATION GAP IN SUB-SCANNING DIRECTION
JUDGE Δ
OK
NG
ADJUST INCIDENT POSITION
COMPUTE AND CORRECT MISREGISTRATION
ADHERE AND FIX TORIC LENS
COMPUTE AND CORRECT IRRADIATION GAP IN SUB-SCANNING DIRECTION AT CENTER OF IMAGE HEIGHT
MEASURE IRRADIATED POSITION IN SUB-SCANNING DIRECTION AT CENTER OF IMAGE HEIGHT
JUDGE
OK
NG
ADJUST IRRADIATED POSITION
COMPLETE ADJUSTING

FIG. 5

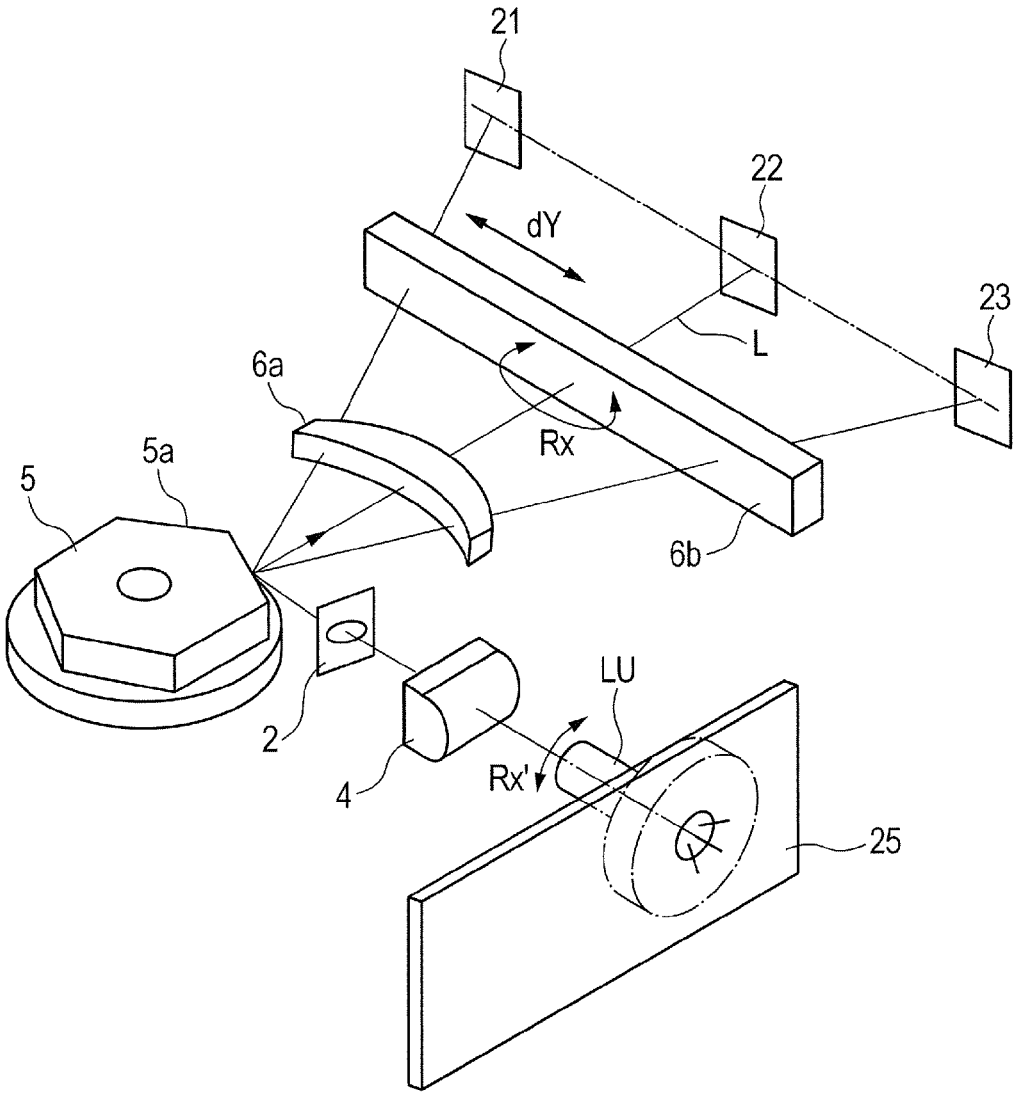


FIG. 6A

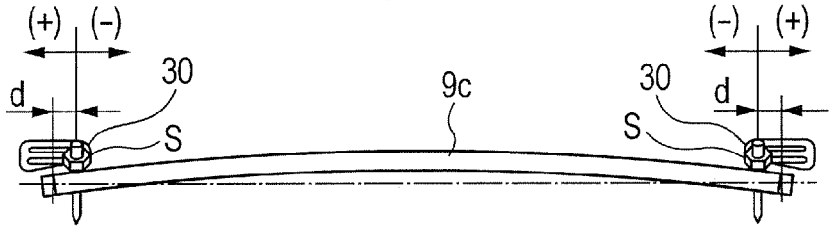


FIG. 6B

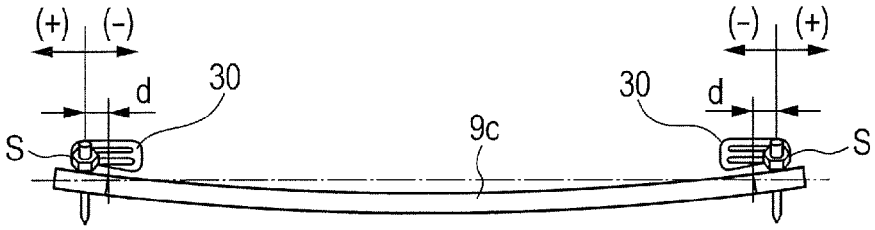


FIG. 7

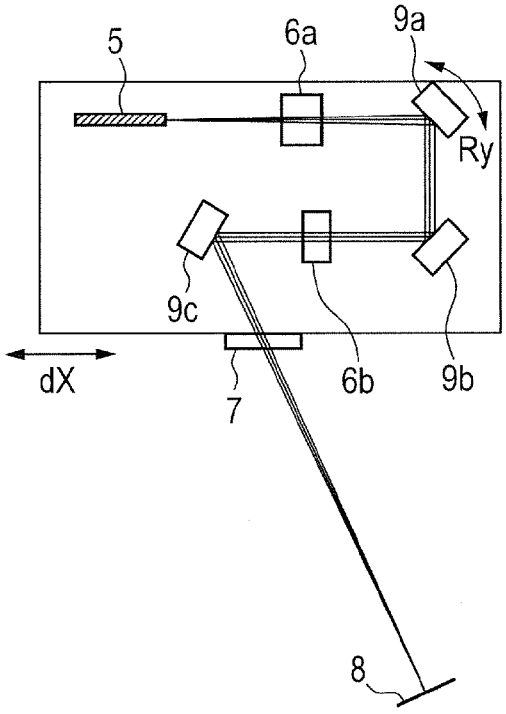


FIG. 8

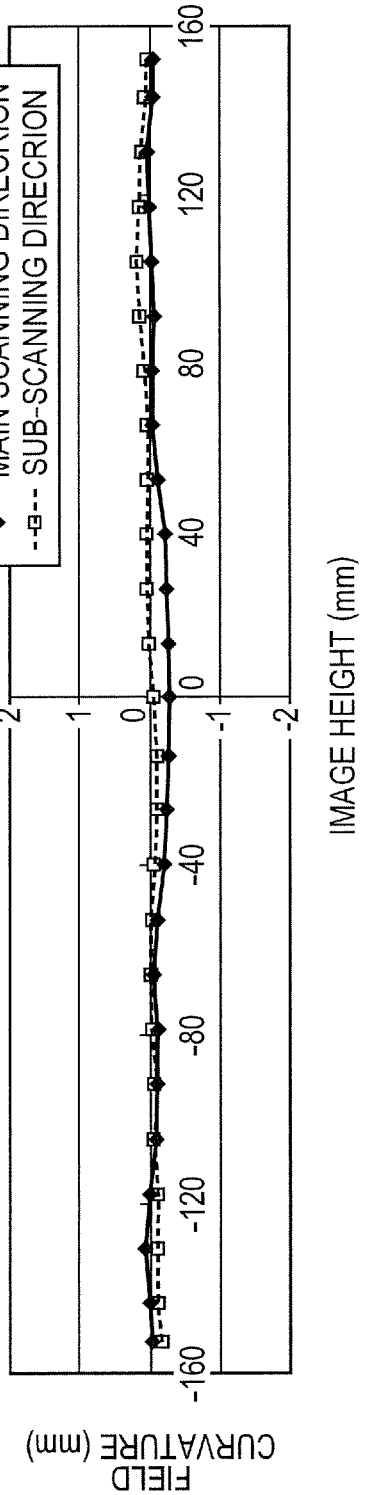

MAIN SCANNING DIRECRION
SUB-SCANNING DIRECRION
2
1
0
-1
-2
160
120
80
40
0
-40
-80
-120
-160
FIELD CURVATURE (mm)
IMAGE HEIGHT (mm)

FIG. 9

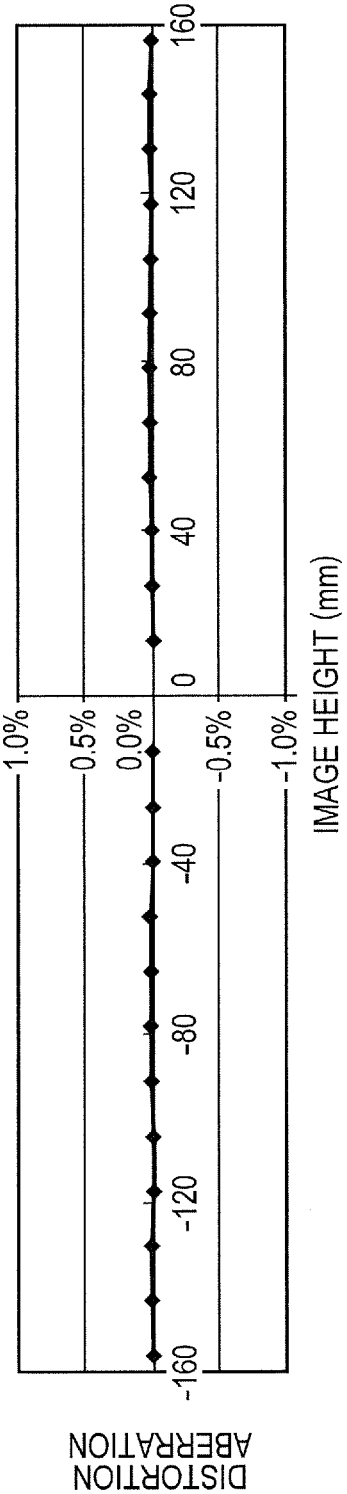

1.0%
0.5%
0.0%
-0.5%
-1.0%
160
120
80
40
0
-40
-80
-120
-160
DISTORTION ABERRATION
IMAGE HEIGHT (mm)

FIG. 10A

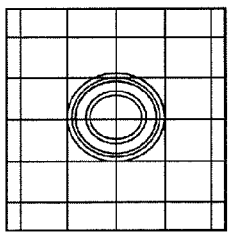


FIG. 10B

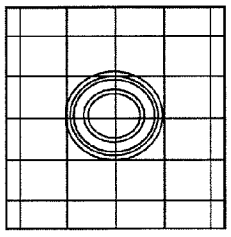


FIG. 10C

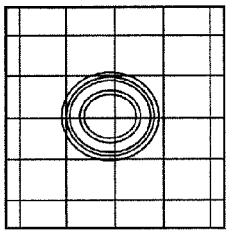


FIG. 10D

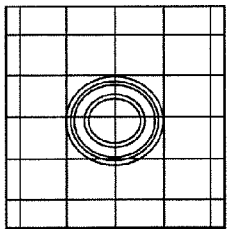


FIG. 10E

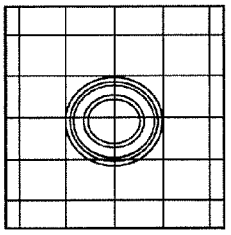


FIG. 11A

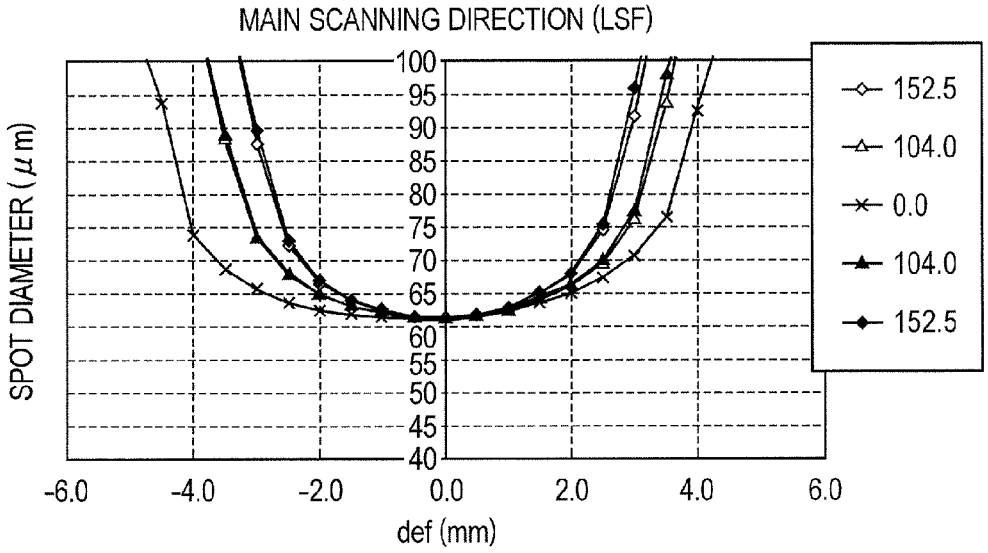


FIG. 11B

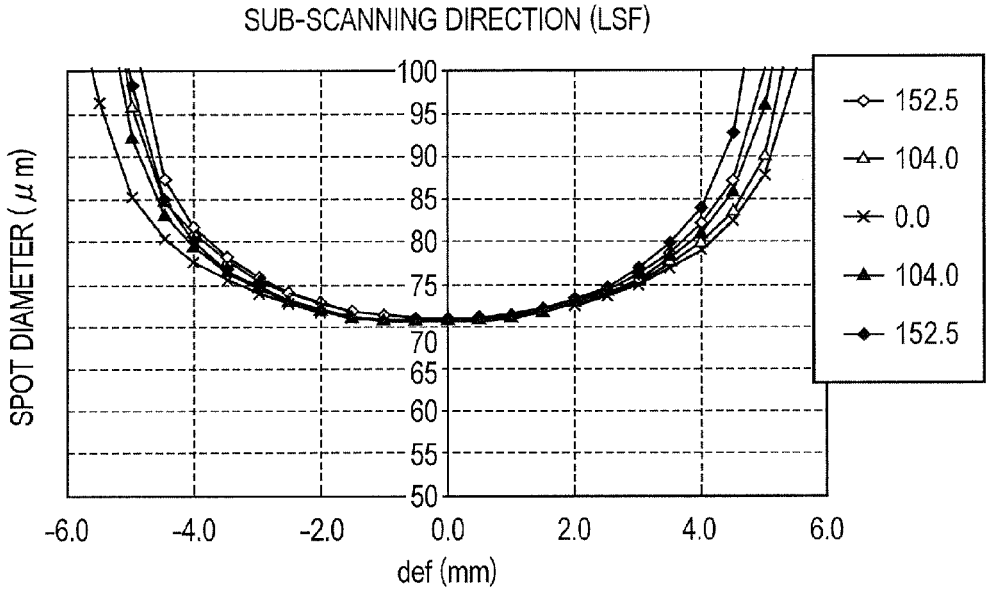


FIG. 12

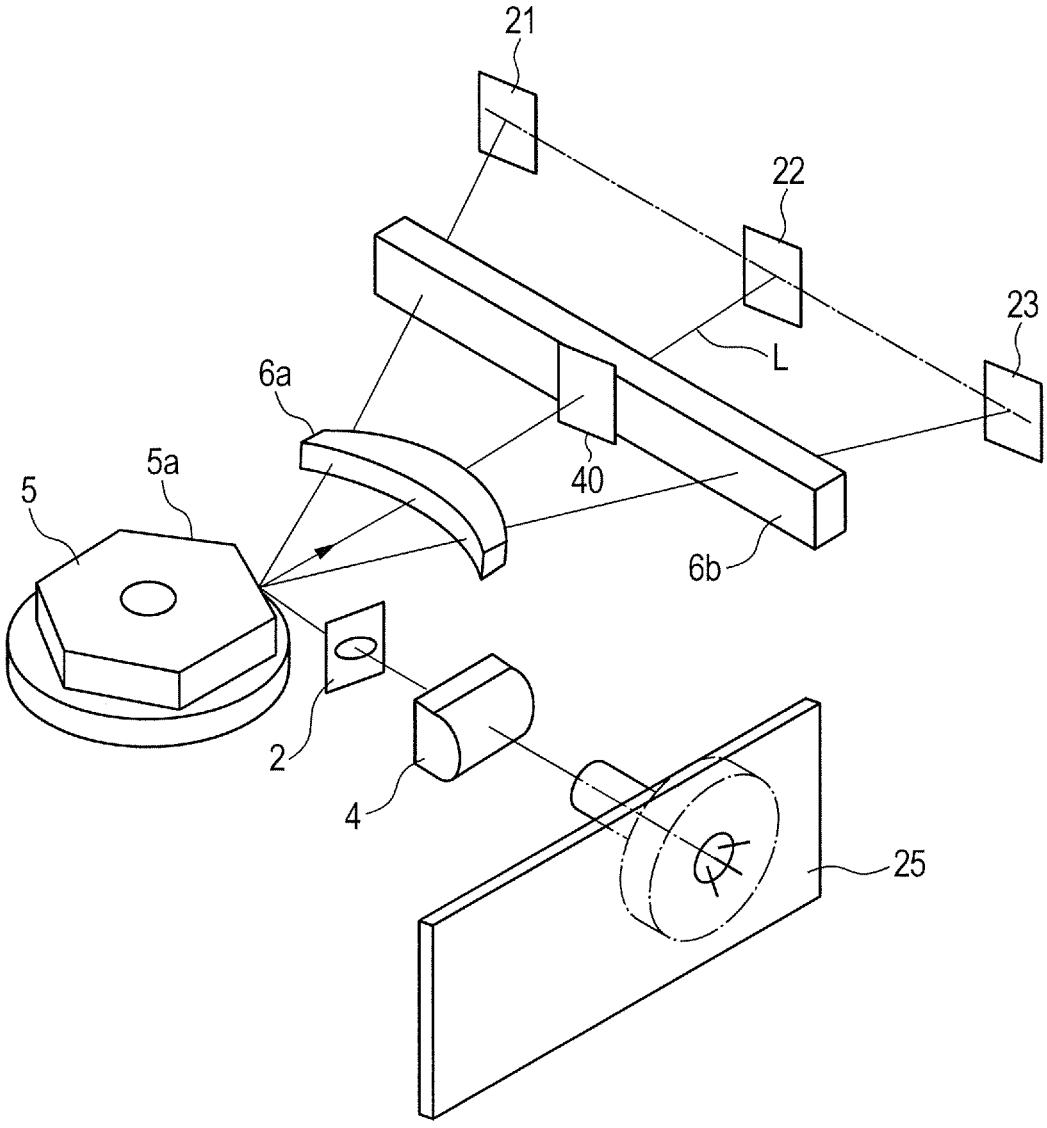


FIG. 13

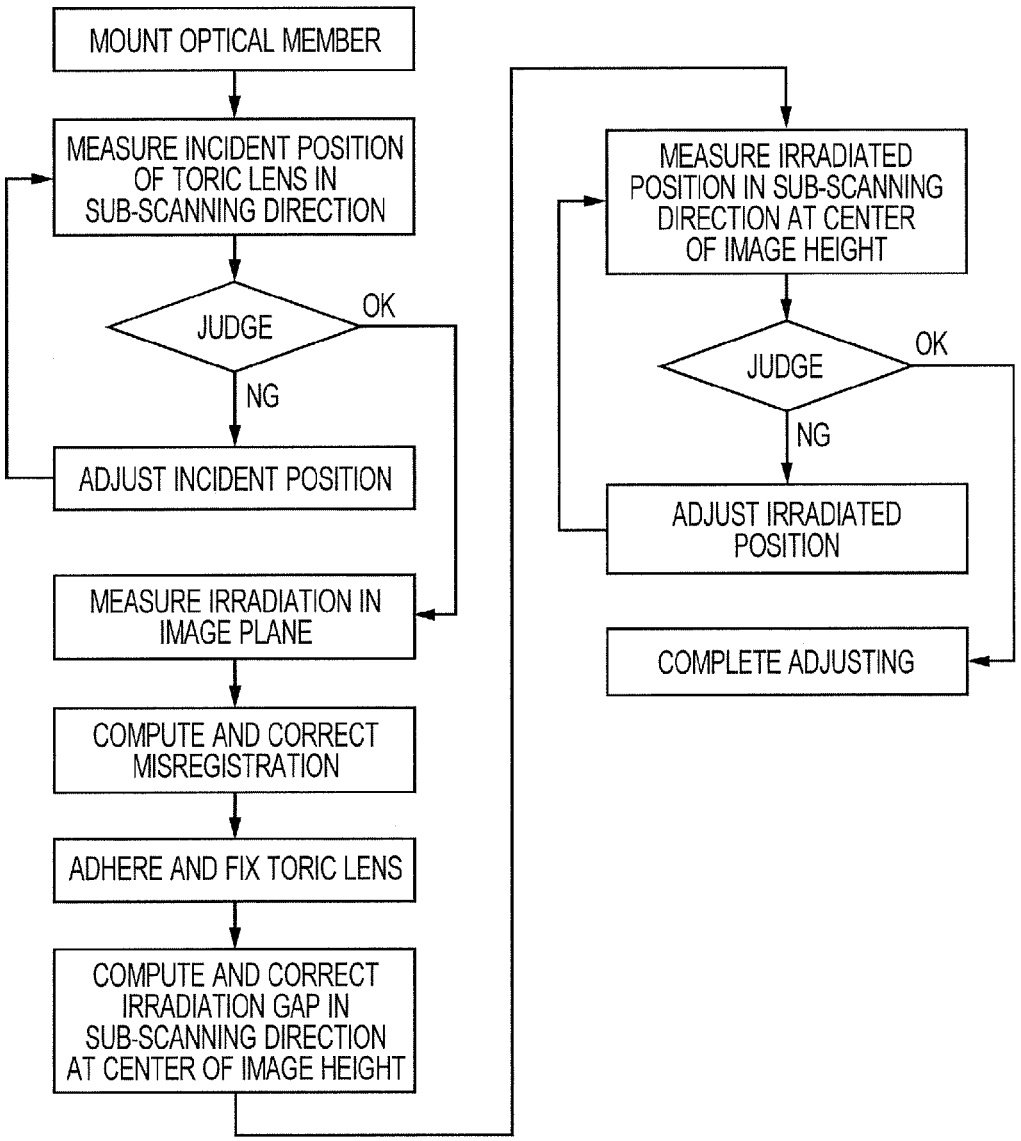

MOUNT OPTICAL MEMBER
MEASURE INCIDENT POSITION OF TORIC LENS IN SUB-SCANNING DIRECTION
JUDGE
OK
NG
ADJUST INCIDENT POSITION
MEASURE IRRADIATION IN IMAGE PLANE
COMPUTE AND CORRECT MISREGISTRATION
ADHERE AND FIX TORIC LENS
COMPUTE AND CORRECT IRRADIATION GAP IN SUB-SCANNING DIRECTION AT CENTER OF IMAGE HEIGHT
MEASURE IRRADIATED POSITION IN SUB-SCANNING DIRECTION AT CENTER OF IMAGE HEIGHT
JUDGE
OK
NG
ADJUST IRRADIATED POSITION
COMPLETE ADJUSTING

FIG. 14

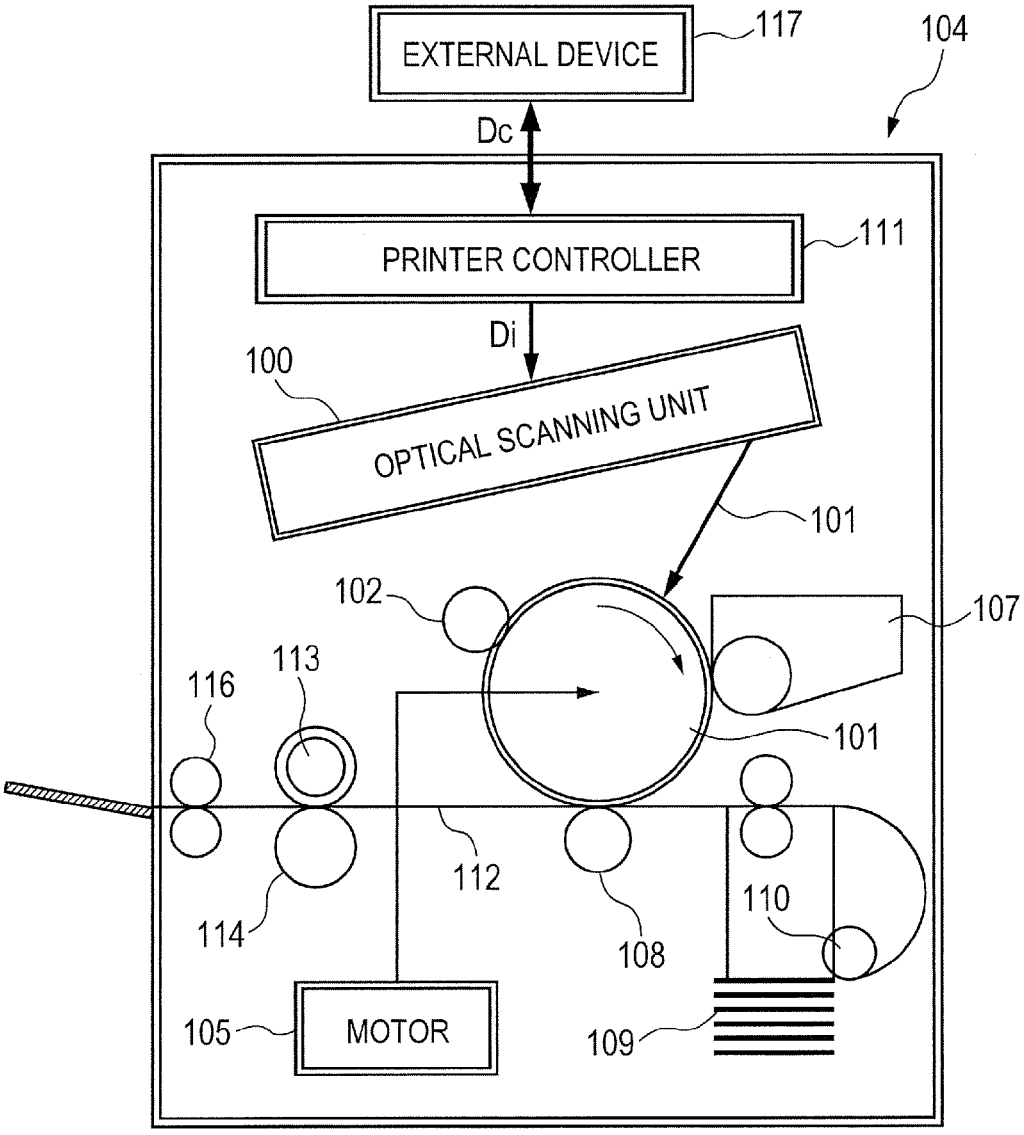
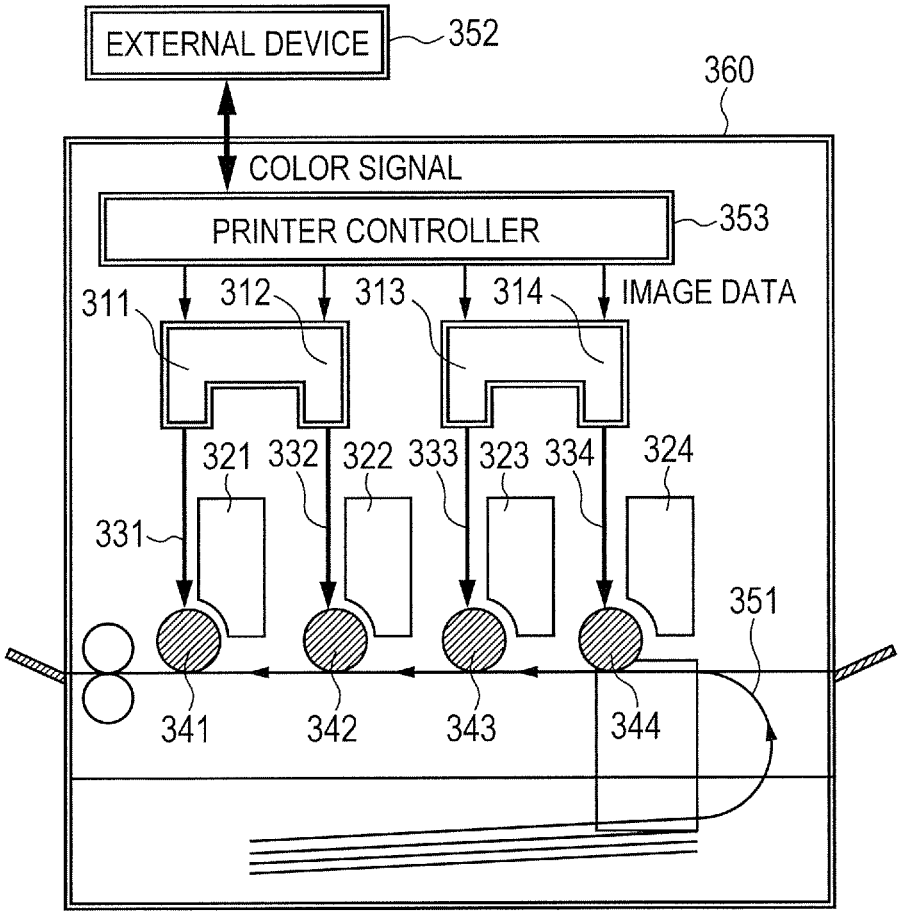

EXTERNAL DEVICE
117
104
Dc
PRINTER CONTROLLER
111
Di
100
OPTICAL SCANNING UNIT
101
102
107
116
113
101
112
114
108
110
105
MOTOR
109

FIG. 15


EXTERNAL DEVICE
352
360
COLOR SIGNAL
PRINTER CONTROLLER
353
311
312
313
314
IMAGE DATA
321
332
322
333
323
334
324
331
351
341
342
343
344

METHOD OF ASSEMBLING AND ADJUSTING A MULTI-BEAM SCANNING OPTICAL APPARATUS AND METHOD OF MANUFACTURING A MULTI-BEAM SCANNING OPTICAL APPARATUS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a method of assembling and adjusting a multi-beam scanning optical apparatus and a method of manufacturing a multi-beam scanning optical apparatus, and more particularly, to a method of assembling and adjusting a multi-beam scanning optical apparatus and a method of manufacturing a multi-beam scanning optical apparatus, which are suitable for a multi-beam scanning optical apparatus used for an image forming apparatus employing an electrophotographic process, such as a laser beam printer, a digital copy machine, and a multi-function printer.

2. Description of the Related Art

In a scanning optical apparatus of an image forming apparatus such as a laser beam printer (LBP), conventionally, a light beam emitted from a light source unit, which is optically modulated in accordance with an image signal, is periodically deflected by a deflecting unit including a rotating polygon mirror. The light beam that has undergone deflection scanning is then focused on a surface of a photosensitive recording medium (photosensitive drum) in a spot shape by an imaging optical system having an fθ characteristic to optically scan the surface, thus recording an image on the surface of the photosensitive recording medium.

Under increasing need for a printing machine having a high printing speed, adequate measures taken in the scanning optical apparatus include, for example, (1) increasing the rotation speed of a deflecting unit (such as the polygon mirror), (2) increasing the number of mirror planes of the polygon mirror, and (3) increasing the number of light beams (using a multi-beam laser, combining light beams by using a prism, or causing multiple light beams to be entered into a polygon mirror at different angles in a deflecting direction). However, the measures (1) and (2) raise such problems as a limit of the rotation speed and a restriction of a size of the polygon mirror due to the increase of the number of the mirror planes thereof, respectively, and hence a multi-beam scanning optical apparatus using a multi-beam light source of the measure (3) is increasingly used.

However, in the multi-beam scanning optical apparatus, a scanning interval misalignment or a scanning position misalignment (misregistration) in a sub-scanning direction of the multi-beam may occur due to a mounting error of each optical element. To cope with this problem, Japanese Patent Application Laid-Open No. H10-319336 discloses a method of adjusting a sub-scanning interval of the multi-beam on a surface of a photosensitive drum, in which a semiconductor laser is rotated about a center axis. In addition, although a multi-beam laser is not employed, Japanese Patent Application Laid-Open No. H11-326804 discloses an adjustment method of suppressing a misregistration in a sub-scanning direction between different colors by turning a diffractive optical element in a color image forming apparatus including multiple scanning optical apparatus. Further, as disclosed in Japanese Patent Application Laid-Open No. 2004-258182, a method of correcting a misregistration of a scanning line in a sub-scanning direction has been known, in which an imaging optical element is moved in the sub-scanning direction.

However, when the methods described in Japanese Patent Application Laid-Open No. H11-326804 and Japanese Patent Application Laid-Open No. 2004-258182 are applied to correct the scanning position misalignment (misregistration) in the multi-beam scanning optical apparatus, there occurs a problem that the sub-scanning interval between beams of the multi-beam on the surface of the photosensitive drum becomes non-constant relative to an image height. This phenomenon is caused by a fact that, when the imaging optical element is moved to correct the scanning position misalignment (misregistration) in the sub-scanning direction, a sub-scanning position on the imaging optical element is largely deviated from a position on which the multiple laser beams are supposed to be incident.

SUMMARY OF THE INVENTION

In view of the above, the present invention provides a method of assembling and adjusting a multi-beam scanning optical apparatus and a method of manufacturing a multi-beam scanning optical apparatus that enable a high-speed and highly-fine printing by sufficiently correcting a scanning position misalignment of a multi-beam with a uniform multi-beam interval in a sub-scanning direction.

According to one aspect of the present invention of a method of assembling and adjusting a multi-beam scanning optical apparatus, the method includes a light source unit having multiple light emitting points, a deflecting unit configured to deflect multiple light beams emitted from the light source unit, and an imaging optical system configured to image the multiple light beams deflected by the deflecting unit on a surface to be scanned, the method including: adjusting incident positions of the multiple light beams in a sub-scanning direction, which are entered into an imaging optical element constituting the imaging optical system, to thereby adjust irradiated positions of the multiple light beams on the surface to be scanned; and adjusting the irradiated positions of the multiple light beams on the surface to be scanned in the sub-scanning direction without changing the incident positions.

According to the present invention, degradation of an image can be suppressed and a high-speed and highly-fine printing can be achieved in the multi-beam scanning optical apparatus.

Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a view illustrating a main-scanning cross section of a scanning optical apparatus according to a first embodiment of the present invention.

FIG. **1**B is a view illustrating a sub-scanning cross section of the scanning optical apparatus according to the first embodiment of the present invention.

FIG. **2**A is a diagram illustrating a phase matching of the multi-beam scanning optical apparatus.

FIG. **2**B is a diagram illustrating the phase matching of the multi-beam scanning optical apparatus.

FIG. **3**A is a diagram illustrating an asymmetry of a sub-scanning irradiation position interval of a multi-beam due to a change of posture of a mirror **9***a*.

FIG. **3**B is a diagram illustrating the asymmetry of the sub-scanning irradiation position interval of the multi-beam due to the change of posture of the mirror **9***a*.

FIG. **4** is a flowchart of an assembling and adjusting process according to the first embodiment of the present invention.

FIG. **5** is a diagram illustrating sensor arrangement and adjustment directions according to the first embodiment of the present invention.

FIG. **6**A is a diagram illustrating adjustment of a mirror curvature according to the first embodiment of the present invention.

FIG. **6**B is a diagram illustrating the adjustment of the mirror curvature according to the first embodiment of the present invention.

FIG. **7** is a diagram illustrating another method of adjusting an irradiated position according to the first embodiment of the present invention.

FIG. **8** is a graph showing an amount of a field curvature according to the first embodiment of the present invention.

FIG. **9** is a graph showing an fθ characteristic of an optical system according to the first embodiment of the present invention.

FIG. **10**A is a diagram illustrating a spot profile on a surface to be scanned according to the first embodiment of the present invention (Y=−156 mm).

FIG. **10**B is a diagram illustrating the spot profile on the surface to be scanned according to the first embodiment of the present invention (Y=−104 mm).

FIG. **10**C is a diagram illustrating the spot profile on the surface to be scanned according to the first embodiment of the present invention (Y=0 mm).

FIG. **10**D is a diagram illustrating the spot profile on the surface to be scanned according to the first embodiment of the present invention (Y=+104 mm).

FIG. **10**E is a diagram illustrating the spot profile on the surface to be scanned according to the first embodiment of the present invention (Y=+156 mm).

FIG. **11**A is a graph showing a defocus characteristic of a spot diameter according to the first embodiment of the present invention.

FIG. **11**B is a graph showing the defocus characteristic of the spot diameter according to the first embodiment of the present invention.

FIG. **12** is a diagram illustrating a sensor arrangement according to a second embodiment of the present invention.

FIG. **13** is a flowchart of an assembling and adjusting process according to the second embodiment of the present invention.

FIG. **14** is a view illustrating a sub-scanning cross section of an image forming apparatus according to an embodiment of the present invention.

FIG. **15** is a schematic diagram illustrating main parts of a color image forming apparatus according to an embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

Exemplary embodiments of the present invention are now described in detail with reference to the accompanying drawings.

First Embodiment

FIG. **1**A is a view illustrating a main-scanning cross section of a scanning optical apparatus according to a first embodiment of the present invention. FIG. **1**B is a view illustrating a sub-scanning cross section of the scanning optical apparatus according to the first embodiment of the present invention. The main scanning direction (Y direction) identifiable in this context is a direction perpendicular to a rotation axis of a deflecting unit **5** and an optical axis of an imaging optical system **6** (X direction) (a direction along which a light beam is deflected by the deflecting unit **5** (deflection scanning)). The sub-scanning direction (Z direction) identifiable in this context is a direction parallel to the rotation axis of the deflecting unit **5**. The main-scanning cross section identifiable in this context is a plane including the optical axis of the imaging optical system **6** and the main scanning direction. The sub-scanning cross section identifiable in this context is a cross section including the optical axis of the imaging optical system **6** and perpendicular to the main-scanning cross section.

As illustrated in FIG. **1**A, a light source unit (e.g., a semiconductor laser) **1** includes multiple light emitting points (**1***a* and **1***b*). Diverged light fluxes emitted from the light source unit **1** (**1***a* and **1***b*) are converted into substantially collimated light beams by a collimator lens **3** (**3***a* and **3***b*). The converted substantially collimated light beams are imaged near a deflecting surface **5***a* of the polygon mirror (deflecting unit) **5** as a dine image elongated in the main scanning direction by a cylindrical lens **4** that has a power only in the sub-scanning direction. A width of the light beam entered into the cylindrical lens **4** is limited in both the main scanning direction and the sub-scanning direction by an aperture stop **2**. The aperture stop **2**, the collimator lens **3**, and the cylindrical lens **4** constitute an incident optical system.

The optical deflector **5** as the deflecting unit includes, for example, a rotating polygon mirror, being rotated at a constant speed in a direction of an arrow A illustrated in FIG. **1**A by a driving unit (not shown) such as a motor.

Imaging optical elements (toric lenses) **6***a* and **6***b* having an fθ characteristic image the light beams deflected by the optical deflector **5** on a photosensitive drum surface (surface to be scanned) **8** in a spot shape. The scanning optical apparatus according to the first embodiment further includes reflecting mirrors **9***a*, **9***b*, and **9***c* and a dustproof glass **7**. With a rotation of the polygon mirror **5** in the direction of the arrow A, the photosensitive drum surface **8** is optically scanned in a direction of an arrow B to form a scanning line (not shown), and thus an image recording is performed. The toric lenses **6***a* and **6***b* have a function of correcting an angle error by causing the deflecting surface **5***a* of the optical deflector **5** or its neighborhood and the photosensitive drum surface **8** or its neighborhood to establish a conjugate relation in the sub-scanning cross section. The toric lenses **6***a* and **6***b* and the reflecting mirrors **9***a*, **9***b*, and **9***c* constitute the imaging optical system.

An optical unit that is mentioned below is a unit including the light source unit, the incident optical system, the deflecting unit, and the imaging optical system.

A profile of an optical functional surface of the toric lenses **6***a* and **6***b* according to the first embodiment is expressed by the following equations. Given that an intersection of each lens surface of the toric lenses **6***a* and **6***b* and the optical axis is set to the origin, a direction of the optical axis is set to the x axis, direction perpendicular to the optical axis in the main-scanning cross section is set to the y axis, and a direction perpendicular to the optical axis in the sub-scanning cross section is set to the z axis, for the meridional direction corresponding to the main scanning direction, the profile is expressed by

$$x = \frac{y^2/R}{1+\sqrt{1-(1+k)y^2/R^2}} + A_2y^2 + A_4y^4 + A_6y^6 + A_8y^8 + A_{10}y^{10} \quad \text{(Equation A)}$$

where R is a curvature radius and k, A_4, A_6, A_8, and A_{10} are aspherical coefficients. For the sagittal direction corresponding to the sub-scanning direction (a direction including the optical axis and perpendicular to the main scanning direction), the profile is expressed by

$$x = \frac{cz^2}{1+\sqrt{1-c^2z^2}} \quad \text{(Equation B)}$$

$$c = c_0 + B_2y^2 + B_4y^4 + B_6y^6 + B_8y^8 + B_{10}y^{10}$$

where c_0 is a sagittal curvature on the optical axis and B_2, B_4, B_6, B_8, and B_{10} are coefficients.

In the multi-beam scanning optical apparatus, multiple light emitting points are disposed at an angle within a predetermined range in the main scanning direction and the sub-scanning direction. Therefore, as illustrated in FIG. **2**A, a light beam A**1** and a light beam B**1** respectively emitted from the multiple light emitting points **1***a* and **1***b* are entered into different positions apart from each other in the main scanning direction on the deflecting surface of the optical deflector (polygon mirror), and angles of the light beams reflected and deflected by the optical deflector are also different from each other. Therefore, spots are imaged on different positions apart from each other in the main scanning direction on the photosensitive drum surface **8**. For this reason, in the multi-beam scanning optical apparatus having this configuration, image data is sent with a shifted timing by a predetermined time δT such that an imaging position of a light beam in the main scanning direction from another light emitting point is matched to a point on the surface to be scanned in the main scanning direction at which a predetermined reference light emitting point is imaged. The deflecting surface **5***a* with the timing shifted by δT is set to an angle of a deflecting surface **5***b* illustrated in FIG. **2**B, and a light beam B**2** reflected and deflected by the deflecting surface **5***b* at this time is reflected and deflected in a direction of a light beam B**2'**, i.e., the same direction of a light beam A**1'** as the light beam A**1**. As a result, the imaging points of the spots in the main scanning direction match each other.

A fluctuation of irradiated positions of multiple light beams emitted from the light source unit **1** on the photosensitive drum surface **8** in the sub-scanning direction when a mounting posture of the above-mentioned optical element is changed with respect to the optical unit is reviewed. For example, it is assumed that a posture of the mirror **9***a* is tilted in a direction of Ry as illustrated in FIG. **3**A so that a light beam travels along a locus indicated by a dashed line illustrated in FIG. **3**A and arrives at the photosensitive drum surface **8**. An amount of change of the irradiated position corresponding to each light emitting point (**1***a* and **1***b*) of the multi-beam at three image heights of +152 mm, 0 mm, and −152 mm on the photosensitive drum surface **8** is illustrated in FIG. **3**B. As illustrated in FIG. **3**B, the irradiated position of the light beam from each of the light emitting points in the sub-scanning direction is moved in the same direction with respect to a design position (a dotted line in FIG. **3**B) for all three image heights. However, the amount of change of the irradiated position of each image height is different depending on the light emitting point. The amount of change of the irradiated position of the light beam from the light emitting point **1***a* is decreased as the image height changes from +152 mm to −152 mm, while the amount of change of the irradiated position of the light beam from the light emitting point **1***b* is increased as the image height changes from +152 mm to −152 mm. Therefore, an irradiation position interval between these light beams in the sub-scanning direction is increased as the image height changes from +152 mm to −152 mm, causing an asymmetry.

This phenomenon is caused by a deviation of an incident position, in the sub-scanning direction, of a light beam when the light beam is entered into the toric lens **6***b* that has a power in the sub-scanning direction from a designed position (a position on which the light beam is incident under a condition that all the optical members are in a state of an initial design). By setting a time difference of **6**T as described referring to FIGS. **2**A and **2**B, the light beams (A**1** and B**1**) from the respective light emitting points are incident on different positions of the toric lens **6***b*. Therefore, a power in the sub-scanning direction becomes different due to a refractive power difference because a curvature in the sub-scanning direction is different at a position of the toric lens **6***b* on which the light beam from each of the light emitting points is incident or because an incident angle is different in the main scanning direction. As a result, even if the light beam from each of the light emitting points is entered into the toric lens **6***b* with a shift of the substantially same amount in the sub-scanning direction, the irradiated position on the photosensitive drum surface in the sub-scanning direction is different between the light emitting points because the optical path is different after passing through the toric lens **6***b*. In addition, a magnitude of a main scanning angle at which the light beam from each of the light emitting points is entered into the toric lens **6***b*, is reversed between a case for the image height +152 mm and a case for the image height −152 mm, and hence the asymmetry occurs relative to the image height.

It can be considered that a shift of the irradiated position on the photosensitive drum surface **8** in the sub-scanning direction is corrected by, for example, moving the toric lens **6***b* in the sub-scanning direction. However, the position on the toric lens **6***b* in the sub-scanning direction on which the light beam is incident is still shifted from the designed position, and hence the irradiation position interval between the light beams from the light emitting points on the photosensitive drum surface **8** in the sub-scanning direction remains asymmetric. Up to now, the toric lens **6***b* is moved to suppress the asymmetry of the irradiation position interval in the sub-scanning direction to some extent by shifting intentionally a target value of the irradiated position in the sub-scanning direction in a uniform manner. However, considering a fluctuation in manufacturing a system due to mounting of the optical elements or the like, when the lateral magnification of the imaging optical system is 1.0 or larger, it is not desirable because an irradiation position interval asymmetry Δ in the sub-scanning direction and a sensitivity on the change of the irradiated position due to the fluctuation of the light beam incident position on the toric lens **6***b* in the sub-scanning direction is increased.

To cope with this problem, in the present invention, an assembling and adjusting process is performed based on a flowchart illustrated in FIG. **4**. Each optical member is mounted on the optical unit (not shown), the light emitting points **1***a* and **1***b* are turned on only for a predetermined time while rotating the polygon mirror **5**, and then an irradiated position Y in the main scanning direction and an irradiated

position Z in the sub-scanning direction of the light beams from respective light emitting points, which are entered into optical sensors **21**, **22**, and (first optical sensor) arranged at three image height positions as illustrated in FIG. **5** are detected at position corresponding to the photosensitive drum surface as the surface to be scanned. The optical sensor **22** corresponds to the image height of 0 mm, and the optical sensors **21** and **23** are arranged apart from the optical sensor **22** by the substantially same distance in the main scanning direction. An irradiation position interval of the light beam from each light emitting point on the optical sensors **21** and **23** in the sub-scanning direction is then computed. When coordinates, at which the light beam from the light emitting point **1***a* is entered into the optical sensor **21** are (Y**21***a*, Z**21***a*) and coordinates, at which the light beam from the light emitting point **1***b* is entered into the optical sensor **21** are (Y**21***b*, Z**21***b*), an irradiation position interval Δ**21** of the light beam from each light emitting point in the sub-scanning direction is computed as Z**21***a*'Z**21***b*. Similarly in the optical sensor **23**, an irradiation position interval Δ**23** in the sub-scanning direction is computed as Z**23***a*−Z**23***b*. If the irradiation position interval asymmetry Δ(=Δ**21**−Δ**23**) between two light beams in the sub-scanning direction in the optical sensors **21** and **23** is equal to or larger than a predetermined value, the toric lens **6***b* is moved in the sub-scanning direction by an amount computed from a known sensitivity such that the light beam incident position approaches its designed position. If the asymmetry Δ falls within a predetermined range, the movement of the toric lens **6***b* in the sub-scanning direction is completed (incident position adjustment). Although the irradiation position interval asymmetry in the sub-scanning direction can be adjusted by moving a toric lens having a power in the sub-scanning direction among the toric lenses constituting the imaging optical system, it is preferred to move a toric lens in the sub-scanning direction, which has the largest power in the sub-scanning direction. In the first embodiment, the toric lens **6***b* has the largest power in the sub-scanning direction among the toric lenses constituting the imaging optical system. The toric lens having the largest power in the sub-scanning direction indicates a toric lens that has a larger power in the sub-scanning direction as compared to any other toric lenses in any position in the main scanning direction, which is determined by comparing powers of the toric lenses in the sub-scanning direction in the entire scanning range in the main scanning direction.

Subsequently, a correction for a misregistration is performed. Each of the positions on the optical sensors **21**, **22**, and **23**, on which the light beam from the light emitting point **1***a* is entered, is detected, and then a registration value is computed as follows.

(1) Tilt of the irradiated position in the sub-scanning direction: Z**21***a*'Z**23***a*

(2) Skew of the irradiated position in the sub-scanning direction: (Z**21***a*+Z**23***a*)/2−Z**22***a*

(3) One side magnification of the irradiated position in the main scanning direction: (Y**21***a*+Y**23***a*)−2×Y**22***a*

In the first embodiment, a correction for the tilt of the irradiated position in the sub-scanning direction of the item (1) is performed by rotating the toric lens **6***b* about the optical axis (L in FIG. **5**) in a direction of Rx illustrated in FIG. **5**. The reason why the optical axis of the toric lens **6***b* is taken as the rotation center is because the irradiation position interval asymmetry Δ in the sub-scanning direction corrected above is changed if the rotation center position does not correspond to the optical axis. A correction for the skew of the irradiated position in the sub-scanning direction of the item (2) is performed by curving the mirror **9***c* in a direction of a reflection surface by moving a slider S from side to side while holding down the mirror **9***c* in the direction of the reflection surface with a leaf spring **30** as illustrated in FIGS. **6**A and **6**B. A correction for the one side magnification of the irradiated position in the main scanning direction of the item (3) is performed by moving the toric lens **6***b* in a direction of dY illustrated in FIG. **5**. Although the correction for the misregistration is performed by moving the toric lens **6***b* and deforming the mirror **9***c* in the first embodiment, an electrical correction of the irradiated position can also obtain the same effect on the photosensitive drum surface **8** without causing any problem. Although a case of correcting the misregistration is herein described assuming a scanning optical apparatus to be used for a color image forming apparatus, this correction method can also be applied to a scanning optical apparatus for a monochrome image forming apparatus employing a multi-beam optical system.

At the time when the correction for the misregistration is completed, the toric lens **6***b* is fixed (for example, using an adhesive) to the optical unit. Subsequently, a deviation of an irradiation position interval Δ**22** (=Z**22***a*−Z**22***b*) in the sub-scanning direction in the optical sensor **22** located at the center image height (image height of 0 mm) from an amount computed from a predetermined resolution (DPI) is corrected by, for example, rotating a laser unit LU (a unit in which the light source unit **1** and the collimator lens **3** are integrated) about the optical axis in a direction of Rx' illustrated in FIG. **5**. The laser unit LU is then fixed to the optical unit and an electrical circuit board **25** is mounted thereon.

At this point, the irradiated position Z**22***a* in the sub-scanning direction obtained by the light beam from the light emitting point **1***a* on the optical sensor **22** is still deviated from a predetermined position, and hence, for example, the irradiated position in the sub-scanning direction is corrected (irradiated position adjustment) by rotating the mirror **9***c*, which is a reflecting member located between the toric lens **6***b* and the photosensitive drum surface **8**, in a direction of Ry illustrated in FIG. **1**B. However, the method of correcting the irradiated position in the sub-scanning direction is not limited to the correction by rotating the reflecting member **9***c* located between the toric lens **6***b* and the photosensitive drum surface **8** described as an example in the first embodiment. For example, as illustrated in FIG. **7**, the irradiated position can be adjusted by adjusting a position of an optical unit (dX) while detecting an irradiated position in the sub-scanning direction when mounting the optical unit on a main body of an image forming apparatus and adjusting a relative position with respect to the photosensitive drum surface that is the surface to be scanned. With this step, the process of assembling and adjusting the optical elements is completed.

In the incident position adjustment according to the first embodiment, a movement of the toric lens **6***b* itself in the sub-scanning direction is performed to restore the light beam incident position in the sub-scanning direction of the toric lens **6***b* having a power in the sub-scanning direction to its designed position. However, not only with this method, but also by performing a posture adjustment of the mirror **9***a* or the mirror **9***b* as illustrated in FIG. **7**, the incident position of the light beam on the toric lens **6***b* can be restored to its designed position. The reason why the irradiated position adjustment in the sub-scanning direction is performed by changing the posture of the mirror **9***c* located between the toric lens **6***b* and the photosensitive drum surface **8** is

because a posture change of an optical member subsequent to the toric lens **6***b* (closer to the surface to be scanned than the toric lens **6***b*) does not cause a change of the irradiation position interval in the sub-scanning direction that is previously adjusted. In addition, although the irradiated position adjustment is performed after the incident position adjustment based on the flowchart illustrated in FIG. **4** in the first embodiment, the assembling and adjusting method according to the present invention is not limited thereto, but the incident position adjustment can be performed after the irradiated position adjustment.

In the first embodiment, although a system including a laser light source (light source unit) with two light emitting points is described, if a laser light source with three or more light emitting points is used, light beams emitted from two light emitting points farthest from a light emitting point center of the laser can be detected by the optical sensors. A vertical cavity surface emitting laser (VCSEL) can be used as the light source unit. The vertical cavity surface emitting laser can be easily used to obtain a multi-beam from the configurational merits of its elements and is generally adopted to achieve a high speed and high-resolution operation, and hence applying the present invention to a scanning optical apparatus including the vertical cavity surface emitting laser as the light source unit can obtain a prominent effect. In addition, the present invention can also be applied to a vertical cavity surface emitting laser in which light emitting points are arranged in a two-dimensional array. Table 1 shows optical arrangement, profile, and characteristics of a used glass material of each lens in the optical system according to the first embodiment. Table 2 shows profiles of optical surfaces of the toric lens **6***a* and the toric lens **6***b*. Symbols used in Table 2 are the same as those used in (Equation A) and (Equation B) described above.

TABLE 1

Basic specification		
Operating wavelength	λ (nm)	790
Scanning angle	θ (deg)	39.36
fθ coefficient	f	227.09
Radius of polygon circumscribing circle	R (mm)	20
Number of planes of polygon	M	6
Incident angle in sub-scanning direction	ϵ (deg)	0
Incident angle in deflecting direction	γ (deg)	70
Arrangement of incident system		
Distance between light source and collimator lens	d1 (mm)	30.3
Center thickness of collimator lens 1	d2 (mm)	1.0
Center thickness of collimator lens 2	d3 (mm)	2.0
Distance between collimator lens and cylindrical lens	d4 (mm)	4.9
Center thickness of cylindrical lens	d5 (mm)	2.0
Distance between cylindrical lens and deflecting surface	d6 (mm)	97.1
Refractive index of collimator lens 1	n1	1.78501
Refractive index of collimator lens 2	n2	1.58228
Refractive index of cylindrical lens	n3	1.52397

	Meridional curvature R		Sagittal curvature r	
	First surface	Second surface	First surface	Second surface
Collimator lens 1	43.63	15.52	—	—
Collimator lens 2	15.52	−21.49	—	—
Cylindrical lens	∞	∞	50.65	∞

Arrangement of scanning system		
Distance between deflecting surface and toric lens 1	D1 (mm)	30.0
Center thickness of toric lens 1	D2 (mm)	7.5
Distance between toric lens 1 and toric lens 2	D3 (mm)	91.0
Center thickness of toric lens 2	D4 (mm)	5.5
Distance between toric lens 2 and surface to be scanned	D5 (mm)	132.5
Refractive index of toric lens 1	n4	1.52397
Refractive index of toric lens 2	n5	1.52397

	Meridional curvature R		Sagittal curvature r	
	First surface	Second surface	First surface	Second surface
Toric lens 1	−63.89	−41.72	−1000.00	−1000.00
Toric lens 2	−1162.65	1578.52	−1000.00	−33.28

TABLE 2

	Toric lens 6a		Toric lens 6b	
	First surface	Second surface	First surface	Second surface
R	−6.38933E+01	−4.17172E+01	−1.16265E+03	1.57852E+03
K	−4.85430E+00	−1.30403E+00		−1.37581E+03
A2				
A4	2.88996E−07	7.71306E−10		−1.65228E−07
A6	−2.57796E−10	1.27316E−10		1.15990E−11
A8	−5.11634E−14	−3.66856E−13		−6.81945E−16
A10	9.71935E−17	1.58269E−16		1.79775E−20
C0	−1.00E−03	−1.00E−03	−1.00000E−03	−3.00464E−02
B2				1.47351E−06
B4				−2.54121E−10
B6				2.97387E−14
B8				−1.46895E−18
B10				−3.94788E−25

FIG. **8** shows a field curvature on the surface to be scanned in the optical system according to the first embodiment, and FIG. **9** shows the fθ characteristic of the optical system according to the first embodiment. FIGS. **10**A, **10**B, **10**C, **10**D, and **10**E illustrate spot profiles on the surface to be scanned in the optical system according to the first embodiment (contours of 5%, 10%, 13.5%, 36.8%, and 50% with respect to a peak optical intensity), and FIGS. **11**A and **11**B show spot diameters in the main scanning direction and the sub-scanning direction, respectively, when an image plane position is defocused.

In the imaging optical system according to the first embodiment, an example of amount of the irradiation position interval asymmetry Δ in the sub-scanning direction at the ±152 mm image height when a posture of an optical member arranged in front of the polygon mirror **5** (on the light source unit **1** side) is deviated is shown in Table A sum of values of Δ in Table 3 is 3.7 μm.

TABLE 3

Item	Fluctuation amount	Δ
Tilt of laser unit LU	2.2 arc-minute	1.6 μm
Height shift of aperture stop 2	0.1 mm	1.3 μm
Height shift of cylindrical lens 4	0.03 mm	0.8 μm

The sensitivity on change of the irradiation position interval asymmetry Δ in the sub-scanning direction at the ±152 mm image height when the toric lens **6***b* is moved in a direction of dZ illustrated in FIG. **1**B is 13.0 μm/mm. The sensitivity on change of the irradiated position in the sub-scanning direction on the image plane when the toric lens **6***b*

is moved in the direction of dZ is 2.0 mm/mm, and the sensitivity on change of the irradiated position in the sub-scanning direction when the mirror **9***c* is tilted in the direction of Ry is 0.064 mm/arc-minute. In order to correct the above-mentioned asymmetry of Δ=3.7 μm, it suffices to move the toric lens **6***b* by 3.7/13=0.28 mm in the sub-scanning direction. The irradiated position in the sub-scanning direction is changed by 0.28×2.0=0.56 mm on the image plane by moving the toric lens **6***b*, and hence an adjustment can be taken to restore the irradiated position in the sub-scanning direction to its designed position by tilting the mirror **9***c* in the direction of Ry by 0.56/0.064=8.7 arc-minute.

Second Embodiment

FIG. **12** is a diagram illustrating a sensor arrangement in a method of assembling and adjusting a multi-beam scanning optical apparatus according to a second embodiment of the present invention, in which elements assigned with the same reference symbols are the same as those described in the first embodiment. FIG. **13** is a flowchart of an assembling and adjusting process according to the second embodiment. The second embodiment is different from the first embodiment in that an optical sensor (e.g., a line CCD) **40** (second optical sensor) is arranged right in front of a toric lens **6***b* (on the deflecting unit side). Instead of evaluating the asymmetry by detecting an interval of the irradiated positions in the sub-scanning direction with optical sensors **21** and **23**, a position of the light beam in the sub-scanning direction, which is entered into the toric lens **6***b* is detected with the optical sensor **40**. If a detected incident position ΔZ in the sub-scanning direction is deviated by a predetermined value, an incident position adjustment is performed in the same manner as the first embodiment. In this case, the incident positions of the multiple light beams in the sub-scanning direction, which are entered into the toric lens **6***b* are adjusted by moving the toric lens **6***b* in the sub-scanning direction by ΔZ, thus correcting the irradiation position interval asymmetry in the sub-scanning direction. After correcting the irradiation position interval asymmetry in the sub-scanning direction, the optical sensor **40** is retracted, and in the same manner as the first embodiment, a correction for the misregistration, a correction for the irradiation position interval in the sub-scanning direction at the image height of 0 mm (the center image height), and an irradiated position adjustment in the sub-scanning direction are performed to complete the assembling process.

Image Forming Apparatus

FIG. **14** is a view illustrating a sub-scanning cross section of main parts of an image forming apparatus **104** according to an embodiment of the present invention.

Code data Dc is input from an external device **117** such as a personal computer to the image forming apparatus **104**. The code data Dc is converted into image data (dot data) Di by a printer controller **111**. The image data Di is input to a scanning optical apparatus (optical scanning unit) **100** having the configuration described in the first or second embodiment. A light beam **103** modulated in accordance with the image data Di is emitted from the optical scanning unit **100**. A photosensitive surface of a photosensitive drum **101** is scanned with the light beam **103** in the main scanning direction.

The photosensitive drum **101** serving as an electrostatic latent image bearing member is rotated clockwise by a motor **115**. The photosensitive surface of the photosensitive drum **101** is moved with respect to the light beam **103** in the sub-scanning direction orthogonal to the main scanning direction. At a position above the photosensitive drum **101**, a charging roller **102** abuts on the surface of the photosensitive drum **101** to uniformly charge the surface of the photosensitive drum **101**. The charged surface of the photosensitive drum **101** is irradiated with the light beam **103** scanned by the optical scanning unit **100**, to thereby form an electrostatic latent image.

The electrostatic latent image is developed into a toner image by a developing device **107** arranged to abut on the photosensitive drum **101** on a downstream side of an irradiated position of the light beam **103**, and is then transferred onto a printing sheet **112** that is a transfer target material accommodated in a printing sheet cassette **109** arranged ahead of the photosensitive drum **101** (the right side in FIG. **14**) by a transfer roller **108** arranged to face the photosensitive drum **101**. A feeding roller **110** is arranged at an edge portion of the printing sheet cassette **109**, which feeds the printing sheet **112** in the printing sheet cassette **109** to a conveying path.

The printing sheet **112** on which the unfixed toner image is transferred in the above-mentioned manner is then conveyed to a fixing device arranged behind the photosensitive drum **101**. The fixing device includes a fixing roller **113** having a fixing heater (not shown) inside and a pressure roller **114** arranged in press contact with the fixing roller **113**, and fixes the unfixed toner image on the printing sheet **112** by pressing and heating the printing sheet **112** conveyed from the transfer portion at the press contact portion between the rollers **113** and **114**. A discharge roller **116** is further arranged behind the fixing roller **113**, which discharges the printing sheet **112** outside the image forming apparatus.

Color Image Forming Apparatus

FIG. **15** is a schematic diagram illustrating main parts of a color image forming apparatus **360** according to an embodiment of the present invention.

The color image forming apparatus **360** is a tandem type color image forming apparatus in which four scanning optical apparatus are arranged to record image information in parallel on surfaces of photosensitive drums each serving as an image bearing member. The color image forming apparatus **360** includes scanning optical apparatus **311**, **312**, **313**, and **314** having the configuration described in the first or second embodiment, photosensitive drums **341**, **342**, **343**, and **344** each serving as an image bearing member, developing devices **321**, **322**, **323**, and **324**, and a conveying belt **351**.

Respective color signals of red (R), green (G), and blue (B) are input from an external device **352** such as a personal computer to the color image forming apparatus **360**. The color signals are converted into pieces of image data (dot data) of cyan (C), magenta (M), yellow (Y), and black (B) by a printer controller **353** in the color image forming apparatus. The pieces of image data are input to the scanning optical apparatus, respectively. Light beams **331**, **332**, **333**, and **334** which are modulated in accordance with the respective pieces of image data are emitted from the scanning optical apparatus. Photosensitive surfaces of the photosensitive drums are scanned with the light beams in the main scanning direction. In the color image forming apparatus according to this embodiment, two sets of scanning optical apparatus (**311**, **312**) and (**313**, **314**) are arranged, respectively corresponding to the colors of C, M, Y, and B and recording image signals (image information) in parallel on the surfaces of the photosensitive drums, thus printing a color image at high speed.

The color image forming apparatus according to this embodiment forms latent images of different colors on the

corresponding surfaces of the photosensitive drums by using the light beams based on the pieces of image data with the four scanning optical apparatus as described above. After that, the toner images of different colors are transferred onto a recording material in a superimposing manner to form a full color image.

As the external device **352**, for example, a color image reading apparatus including a CCD sensor can be used. In this case, a color digital copy machine can be built with this color image reading apparatus and the color image forming apparatus **360**.

While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

This application claims the benefit of Japanese Patent Application No. 2011-152856, filed Jul. 11, 2011, and Japanese Patent Application No. 2012-134981, filed Jun. 14, 2012, which are hereby incorporated by reference herein in their entirety.

What is claimed is:

1. A method of manufacturing a multi-beam scanning optical apparatus including a light source unit having multiple light emitting points, a deflecting unit configured to deflect multiple light beams emitted from the light source unit, and an imaging optical system having a first imaging optical element and configured to focus the multiple light beams deflected by the deflecting unit on a single surface to be scanned, the method comprising:

irradiating the first imaging optical element with the multiple light beams;

adjusting locations of incident positions of the irradiated multiple light beams on the first imaging optical element in a sub-scanning direction; and

adjusting locations of irradiated positions of the multiple light beams on the single surface to be scanned in the sub-scanning direction while keeping the locations of the incident positions of the irradiated multiple light beams on the first imaging optical element the same,

wherein the adjusting of the locations of the incident positions comprises moving the first imaging optical element in the sub-scanning direction.

2. The method of manufacturing a multi-beam scanning optical apparatus according to claim **1**, wherein:

the imaging optical system comprises multiple imaging optical elements; and

the first imaging optical element has a largest power in the sub-scanning cross section among the multiple imaging optical elements.

3. The method of manufacturing a multi-beam scanning optical apparatus according to claim **2**, wherein the adjusting of the locations of the incident positions comprises adjusting a posture of a reflecting member arranged between the deflecting unit and the first imaging optical element.

4. The method of manufacturing a multi-beam scanning optical apparatus according to claim **2**, wherein the adjusting of the locations of the irradiated positions comprises adjusting a posture of a reflecting member arranged between the first imaging optical element and the single surface to be scanned.

5. The method of manufacturing a multi-beam scanning optical apparatus according to claim **2**, wherein the adjusting of the locations of the irradiated positions comprises adjusting a relative position between an optical unit including the imaging optical system and the single surface to be scanned.

6. The method of manufacturing a multi-beam scanning optical apparatus according to claim **2**, wherein the adjusting of the locations of the incident positions and the adjusting of the locations of the irradiated positions are performed while detecting the multiple light beams with first optical sensors respectively arranged on at least two image height positions at positions corresponding to the single surface to be scanned.

7. A method of manufacturing a multi-beam scanning optical apparatus including a light source unit having multiple light emitting points, a deflecting unit configured to deflect multiple light beams emitted from the light source unit, and an imaging optical system having a first imaging optical element and configured to focus the multiple light beams deflected by the deflecting unit on a single surface to be scanned, the method comprising:

adjusting incident positions of the multiple light beams on the first imaging optical element in a sub-scanning direction; and

adjusting irradiated positions of the multiple light beams on the single surface to be scanned in the sub-scanning direction without changing the incident positions on the first imaging optical element, wherein:

the adjusting of the incident positions and the adjusting of the irradiated positions are performed while detecting the multiple light beams with first optical sensors respectively arranged on at least two image height positions at positions corresponding to the single surface to be scanned;

the adjusting of the incident positions is performed while detecting the multiple light beams with a second optical sensor arranged on the deflecting unit side of the first imaging optical element; and

the adjusting of the irradiated positions is performed while detecting the multiple light beams with the first optical sensors.

8. The method of manufacturing a multi-beam scanning optical apparatus according to claim **1**, wherein the adjusting of the locations of the irradiated positions is performed after the adjusting of the locations of the incident positions.

9. The method of manufacturing a multi-beam scanning optical apparatus according to claim **1**, wherein: the multi-beam scanning optical apparatus includes dustproof glass disposed between the imaging optical system and the single surface to be scanned, and the adjusting locations of irradiated positions is performed while keeping the locations of the incident positions of the irradiated multiple light beams on the first imaging optical element and a location of the dustproof glass the same.

10. The method of manufacturing a multi-beam scanning optical apparatus according to claim **1**, further comprising mounting the light source unit, the deflecting unit, and the imaging optical system to an optical unit.

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